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**Chemical Release and Radiation Effects  
Experiment Advanced Planned  
(5-32156)**

Final Technical Report for the Period  
May 19, 1989 through May 19, 1990

(May 1990)

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**NASA**National Aeronautical and  
Space Agency

# Report Document Page

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16. Abstract  This report summarizes the efforts conducted to provide assessments and planning support for the Chemical Release and Radiation Experiment (CRRES). Included are activities regarding scientific working group and workshop development including the preparation of descriptive information on the CRRES Project.			
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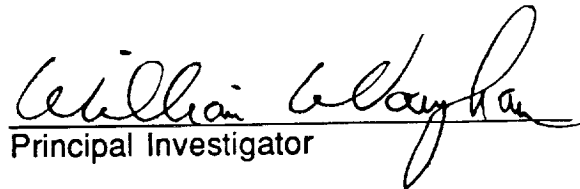


## PREFACE

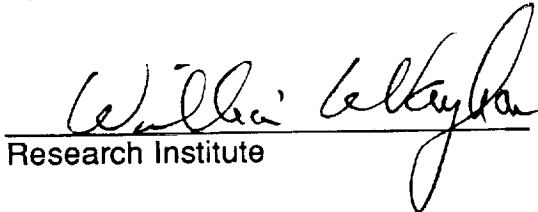
This technical report was prepared by the Research Institute of the University of Alabama in Huntsville. This report is to serve as documentation of technical work performed under contract number NAS8-36955, Delivery Order 45. Dr. William W. Vaughan was the Principal Investigator. Technical work was accomplished under the direction of Ms. Melanie A. Alzmann. Dr. David Reasoner of the NASA/MSFC Space Sciences Laboratory provided technical coordination.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official National Aeronautics and Space Administration position, policy or decision unless so designated by other official documentation.

I have reviewed this report, dated May 19, 1980 and the report contains no classified information.

  
Principal Investigator

Approved:

  
Research Institute

1. The first part of the document is a letter from the President of the United States to the Congress, dated January 3, 1862. It is a very long letter, and it contains a great deal of information about the state of the country at that time. It is a very important document, and it is one of the most important documents in the history of the United States.

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## **I. Statement of Work**

### **CHEMICAL RELEASE AND RADIATION EFFECTS EXPERIMENT ADVANCED PLANNING**

- (1) The contractor shall provide the assessment and solar terrestrial/magnetospheric advance planning concepts for the Chemical Release and Radiation Experiment (CRRES) Satellite project through participation in science study groups and coordination and documentation of meetings, status, problem areas and action items.
- (2) During the course of project development, the contractor shall perform reviews and critiques to broaden the definition, or broaden the scientific community involvement in the project, through the organization and the participation in workshops involving a large segment of the science community and provide subsequent documentation of workshop and project activity.
- (3) Collaborate with the MSFC scientists and engineers on science studies and participate in science/engineering team meetings.
- (4) As the project evolves, the contractor shall provide special emphasis consultant personnel, where required, for assessments of concepts and approaches which may cause significant revisions or improvements in the project. This work also shall include the desired documentation of the project activity.



## II. Summary of Meetings and Workshops

During the contract period, assessment and coordination of the CRRES project scientific investigators was undertaken and accomplished. Meetings were held for scientific work as well as engineering/team meetings. The contractor coordinated and participated in all meetings listed below.

- (1) May 1989: Sounding Rocket Campaign Meeting

NASA/Wallops Island, VA

Documentation of the meeting activities was accomplished by the contractor and distributed to attendees. A copy is on permanent file in the University of Alabama in Huntsville's Research Institute office. An Agenda of the meeting is included herewith for the purposes of this final report.

- (2) August 1989: Investigators Working Group #11

Palo Alto, CA (Lockheed)

Documentation of the meeting was accomplished by the contractor and distributed to attendees. A copy is on permanent file at the University of Alabama in Huntsville's Research Institute office. An Agenda of the meeting is included herewith for the purposes of this final report.

- (3) August 1989: Aircraft Support Meeting

NASA/AMES Research Center, CA

Documentation of the meeting was accomplished by the contractor, and distributed to attendees, and is on permanent file at the University of Alabama Research Institute office. An Agenda of the meeting is included herewith for the purposes of this final report.

- (4) October 1989: CRRES-SPACERAD TEAM MEETING

Ball Space Systems Division, Boulder, CO

Participation in this team meeting was undertaken and accomplished by the contractor, acting as representative for the CRRES Project Scientist.

- (5) March 1990: Aircraft Support meeting

NASA/Marshall Space Flight Center, AL

Documentation of the meeting was accomplished by the contractor and distributed to attendees. A copy is on permanent file at the University of Alabama in Huntsville's Research Institute office. An Agenda of the meeting is included herewith for the purposes of this final report.

(6) March 1990: Investigators Working Group #12

Clemson University, SC

Documentation of the meeting was accomplished by the contractor and distributed to attendees. A copy is on permanent file at the University of Alabama in Huntsville's Research Institute office. An Agenda of the meeting is included herewith for the purposes of this final report.

### **III. Detail Agendas of Meetings and Workshops**

- (1) Kwajalein and Puerto Rico Campaigns Meetings, May 22 - 23, 1989
- (2) CRRES Investigators Working Group #11, August 15, 1989
- (3) Aircraft Support Meeting, August, 17, 1989
- (4) CRRES - SPACERAD (ATLAS)  
Science Team Meeting October 31 - November 2, 1989
- (5) Aircraft Support Meeting, March 6, 1990
- (6) CRRES Investigators Working Group #12, March 13-15, 1990



**KWAJALEIN CAMPAIGN MEETING  
AGENDA  
MAY 22, 1989  
WALLOPS FLIGHT FACILITY, VA**

0830 INTRODUCTION ROBERT FROSTROM  
CAMPAIGN MANAGER

0835 BACKGROUND AND CAMPAIGN OVERVIEW DAVID L. RANSOME  
PROJECT SCIENTIST

0900 KWAJALEIN RANGE CAPABILITIES BUCK BLACKWELL  
USAKA

1000 DETAILED SCIENCE OBJECTIVES  
AND REQUIREMENTS  
A. CRRES  
B. EQUIS/NICARE2  
C. EQUIS/SPREAD "F"  
DR. MICHAEL MENDILLO  
DR. PAUL BERNHARDT  
DR. MICHAEL KELLEY  
DR. ROB PFAFF

LUNCH

1300 PROJECT MANAGER STATUS REPORTS JAY BROWN  
PHIL EBERSPEAKER  
JEFF BLAND

1430 RANGE SAFETY USAKA/NASA

1500 DISCUSSION ITEMS  
LAUNCHER REQUIREMENTS  
FIRING CONSOLE  
SHIPPING REQUIREMENTS  
HOUSING  
ALTAIR MODIFICATION AND REQUIREMENTS  
LAUNCH SCENARIO  
PROGRAM COST  
SOUNDING ROCKET  
SCIENTIFIC

**PUERTO RICO CAMPAIGN MEETING**  
**AGENDA**  
**May 23, 1989**  
**WALLOPS FLIGHT FACILITY, VA**

A CRRES Puerto Rico Campaign Investigators Working Group meeting is scheduled for May 23, 1989, in building E-104, Room 212, beginning at 0900.

The agenda is as follows:

INTRODUCTION	DEBRA FROSTROM CAMPAIGN MANAGER
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SCIENCE OVERVIEW	DAVID REASONER PROJECT SCIENTIST
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DETAILED SCIENCE OBJECTIVES  
AND REQUIREMENTS

AA-1, AA-7	HERB CARLSON
AA-2	FRANK DJUTH
	LEWIS DUNCAN
AA-3	LEWIS DUNCAN
	ED SZCZOCZEWICZ
AA-4	PAUL BERNHARDT

ARECIBO REQUIREMENTS	ALL
GROUND AND AIRCRAFT OBSERVATIONS	ALL

PROJECT MANAGER STATUS	JAY BROWN
------------------------	-----------

CAMPAIGN LOGISTICS	PROJECT TEAM
SHIPPING	
LAUNCHER REQUIREMENTS	
LAUNCH SEQUENCE	
HOUSING	

INTRODUCTION OF POSSIBLE LAUNCHES	MIKE KELLEY
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DEBRA FROSTROM



**CRRES INVESTIGATOR WORKING GROUP #11**  
**AGENDA**  
**AUGUST 15, 1989**  
**PALO ALTO, CA**

0900	INTRODUCTIONS AND WELCOME	ALL
0915	CRRES BASELINE PROGRAM	NASA HQ
0930	CRRES RECOVERY OPTIONS	NASA HQ
0945	POTENTIAL SOVIET INVOLVEMENT	NASA HQ
1000	PEGSAT	R. HOFFMAN
1015	OPERATIONS PLANNING	CRRES PROJECT
1045	UPDATE TO CRRES FUNDING	CRRES PROJECT
1100	CRRES/GTO SATELLITE UPDATE	BASD/CRRES PROJECT
1115	CRRES/GTO LAUNCH AND PERFORMANCE CONSTRAINTS	BASD/CRRES PROJECT
1200	LUNCH	
1330	CRRES/GTO ORBIT CALCULATIONS IDENTIFICATION OF RELEASE OPPORTUNITIES	GENE WESCOTT
1400	OPEN DISCUSSION; CRRES/GTO RELEASE PLANNING	ALL
1700	ADJOURN	
2000	PEGSAT SPLINTER MEETING R. A. Hoffman will chair a meeting of interested parties to discuss the PEGSAT observing campaign. Meeting location TBA.	

**WEDNESDAY, AUGUST 16**

0900	UPDATE ON SOUNDING ROCKETS	M. MENDILLO
0930	SOUNDING ROCKET CANISTERS	C. STOKES
0945	KWAJALELIN CAMPAIGN	R. FROSTROM
1015	PUERTO RICO CAMPAIGN	D. FROSTROM
1045	PRELIMINARY DISCUSSIONS ROCKET OBSERVING CAMPAIGNS	ALL

1200 LUNCH

1330 TRIP TO AMES RESEARCH CENTER  
There will be a trip to the Aircraft Office at Ames Research Center for Interested Parties. This will be a good opportunity to acquaint Ames with our requirements and discuss constraints.

WEDNESDAY EVENING - DINNER AT TBD RESTAURANT

THURSDAY, AUGUST 17

0800	DETAILED DISCUSSIONS OBSERVING CAMPAIGNS, REQUIREMENTS, LOGISTICS INTERACTIONS WITH ARECIBO, MILLSTONE HILL, CSTC	ALL
1130	ADJOURN	

**AIRCRAFT SUPPORT MEETING  
AGENDA  
AUGUST 17, 1989  
NASA AMES RESEARCH CENTER, CA**

0830	Tour Lear and C-141
0930-1030	Experiment requirements/flight planning (241)
0930	Meet with J. Cherbounaux regarding Lear support/ base funding(Howard & Reasoner)
1000	Discuss DC-8 funding with MSFC
1030-1100	Status summary (241)
1100-1200	Unfinished business as required.

Don Anderson- mission planning  
Bob Davidson- experiment requirements  
Bob Morrison- flight planning  
Carl Berg- electrical, avionics,  
communications  
Steve Sluka- airworthiness  
Jack Ratcliff- heliostats  
Earl Petersen/George Alger- aircraft  
programs  
Lou Haughney- C-141 tour

# FIRST CRRES-SPACERAD (ATLAS) SCIENCE TEAM MEETING

## AGENDA

31 October to 2 November, 1989  
Ball Aerospace, Boulder, Colorado

Team Leader: Susan Gussenhoven, AFGL

### TUESDAY, OCTOBER 31

0900	Welcome	Ball Aerospace
0915	CRRES/SPACERAD Status Gary Mullen,	Program manager, AFGL
AFGL DATA PROCESSING		
0945	CRRES/SPACERAD Data Management, Status	Bob McInerney, AFGL
1015	Time history Data Base (Includes Break)	Dennis Delorey, Boston College
1230	Lunch	
1330	Quality Control: AFGL Philosophy	Susan Gussenhoven, AFGL
	: Implementation, Particles	Don Brautigam, AFGL
	: Implementation, Fields	Howard Singer, AFGL
	: and Waves	
1430	NSSDC Participation	Bob McGuire, NSSDC
1500	Break	
1530	Orbital Data Processing and Status of Test Tapes	Al Griffin, AFGL
1700	Ephemeris	RADEX

### WEDNESDAY, NOVEMBER 1

0830	Product Associated Data Bases Subcommittees for Static Models and Engineering Data Support, Outer Zone Dynamics, Cosmic Ray Models, Event Studies, Wave-Particle Interactions, Science Summaries, Other	Susan Gussenhoven, AFGL
0930	Radiation Belt Models, Overview	Bill McNeil, RADEX
1000	Modeling the Outer Zone Electrons	Yam Chiu, Lockheed
1030	Break	
1045	Magnetic Field Models, Comparisons Internal Models	Carolyn Jordan, RADEX
	External Models	Jim Bass, RADEX
1200	Lunch	
1300	Source Surface Model of the Magnetosphere	Michael Schultz, Aerospace

## INSTRUMENT STATUS REPORTS

1330	and to be continued on Thursday	
AFGL-701-2	Dosimeter	Fred hanser, Bronik Dichter, Panametrics
AFGL-701-3	Mos Dosimeter	Bill Stapor, NRL
AFGL-701-7A	Relativistic Protons	Al Vampola, Aerospace
AFGL-701-7B	Proton Switches	Aerospace
AFGL-701-8,9	Proton Telescope	Mike Violet, Bob Redus, AFGL
AFGL-701-4	High Energy Electron Spectrometer	Panametrics
AFGL-701-5A	Middle Energy Electron Spectrometer	Aerospace
AFGL-701-5B	Electron-Proton Angle Spectrometer	Axel Korth, Max Planck
AFGL-701-6	low Energy Particle Analyzer	David Hardy, AFGL
ONR-307-3	Spectrometer for Electrons and Protons	Jack Quinn, Lockheed
ONR-307-8,1,2	Ion Mass Spectrometers	Lockheed
ONR-604	Heavy Nuclei	Murray Perkins, U. Chicage
AFGL-701-11C	Heavy Ion Telescope	Tom Cayton, LANL
AFGL-701-11B	Magnetospheric Ion Composition	David Hall, Rutherford-Appleton
AFGL-701-11A	Low Energy Magnetoshpere Ions	David Young, Southwest Research
AFGL-701-13A	Fluxgate Magnetometer	Howard Singer, AFGL
AFGL-701-13B	Search Coil Magnetometer	Roger Anderson, U. Iowa
AFGL-701-15	Passive Plasma Sounder	U. Iowa
AFGL-701-14	Langmuir Probe	John Wygant, U California, Berkeley
AFGL-701-1A	Microelectronic Package	Gary Mullen, AFGL
AFGL-701-1B	Internal Discharge Monitor	Robb Fredrickson, AFGL
AFAPL-801	Gallium Arsenide Solar Panels	Terry Trumble, AFWAL

### THURSDAY, NOVEMBER 2

0830	Continue Instrument Status Reports	
1130	Satellite Status Report	Ball Aerospace
1200	Lunch	
1300	Reports from Product Associated Data Base Committees	
1400	Instrument Description Publication, Next Meeting, Concerns, etc.	
1430	Adjourn	

**CRRES AIRCRAFT SUPPORT MEETING  
AGENDA  
MARCH 6, 1990**

**MARSHALL SPACE FLIGHT CENTER  
HUNTSVILLE, ALABAMA**

INTRODUCTIONS AND WELCOME	ALL
CRRES CHEMICAL RELEASE MISSION BRIEF OVERVIEW	D. REASONER
NASA DC-8 CONCERNS	J. HUNING
CRITICAL VELOCITY CAMPAIGN	E. WESCOTT
SUMMARY OF AIRCRAFT SUPPORT NEEDS	D. REASONER
ARGUS AIRCRAFT CAPABILITIES	ARGUS PROJECT
ARGUS DATE	ARGUS PROJECT
ARGUS MISSION PLANNING - REQUIREMENTS FOR DATA FROM INVESTIGATORS	ARGUS PROJECT
HALO SUPPORT	AEROMET, INC.
MISSION COORDINATION AND COMMUNICATIONS	ALL
SCHEDULES AND DEADLINES	ALL
ACTION ITEMS	ALL

**CRRES INVESTIGATIONS WORKING GROUP # 12**  
**AGENDA**  
**MARCH 13-15, 1990**  
**CLEMSON UNIVERSITY, SC**

**TUESDAY, MARCH 13**

INTRODUCTIONS AND WELCOME	
INTRODUCTION OF IZMIRAN GUESTS	L. DUNCAN
CRRES - A PROJECT SCIENTIST'S VIEW	D. REASONER
PROGRAMMATIC ISSUES	R. HOWARD
SPACECRAFT UPDATE	J. KIEREIN
LAUNCH DATE AND VEHICLE PERFORMANCE	D. REASONER
CONTINGENCY ISSUES	D. REASONER
KWAJALEIN SOUNDING ROCKETS	R. FROSTROM
PUERTO RICAN SOUNDING ROCKETS	D. FROSTROM
MISSION OPERATIONS AND TRAINING	J. COX
IZMIRAN COLLABORATION PROPOSALS	V. ORAEVSKY
OPEN DISCUSSION - CRRES/IZMIRAN COLLABORATION	ALL

**TUESDAY EVENING - DINNER AT THE CLEMSON HOUSE - DETAILS T.B.A.**

**WEDNESDAY, MARCH 14**

PEGASUS CAMPAIGN UPDATE	R. HOFFMAN
RECENT CIV MODELING	A. DROBOT D. PAPADOPOLOUS
NICARE I RESULTS	P. BERNHARDT
NICARE-I IN-SITU MEASUREMENTS	P. RODRIGUEZ
CRIT-II RESULTS	E. WESCOTT M. KELLEY

**CREES IWG12 AGENDA (CONTINUED)**

**REVIEW OF CAMPAIGN LOGISTICS AND  
REQUIREMENTS**

**D. REASONER/ALL**

- A. GTO CARIBBEAN G1, G9, G11, G12,
- B. PUERTO RICO SOUNDING ROCKETS AA1, AA2, AA3, AA4, AA7
- C. GRAD G8
- D. KWAJALEIN SOUNDING ROCKETS AA5, AA6
- E. SOUTH PACIFIC C.V. G13, G14
- F. GTO HIGH ALTITUDE G2, G3, G4, G5, G6, G7, G10

**THURSDAY, MARCH 15**

**CRRES EDUCATIONAL BROCHURE**

**D. REASONER/ALL**

**ACTION ITEM REVIEW**

**ALL**

**SPLINTER MEETINGS AS DESIRED**

**ADJOURN**



#### IV. CRRES PROGRAM DESCRIPTION

Assessment and coordination was afforded to the CRRES Project Scientist for scientific writing of the CRRES Program Description. Editing and production of the print-ready document were also accomplished. All original photographs and layout are on file at the University of Alabama in Huntsville's Research Institute, having been collected or produced in original form by the contractor. Two key activities were participated in relative to this effort. In addition, documentation of two CRRES experiments was also provided to the CRRES Project Scientist.

(a) October 1989      NICARE

Wallops Island, VA

Written and photographic documentation were accomplished by the contractor for the purpose of inclusion to a CRRES Program Description.

(b) April 1990      PEGSAT

Stoney Rapids, Canada

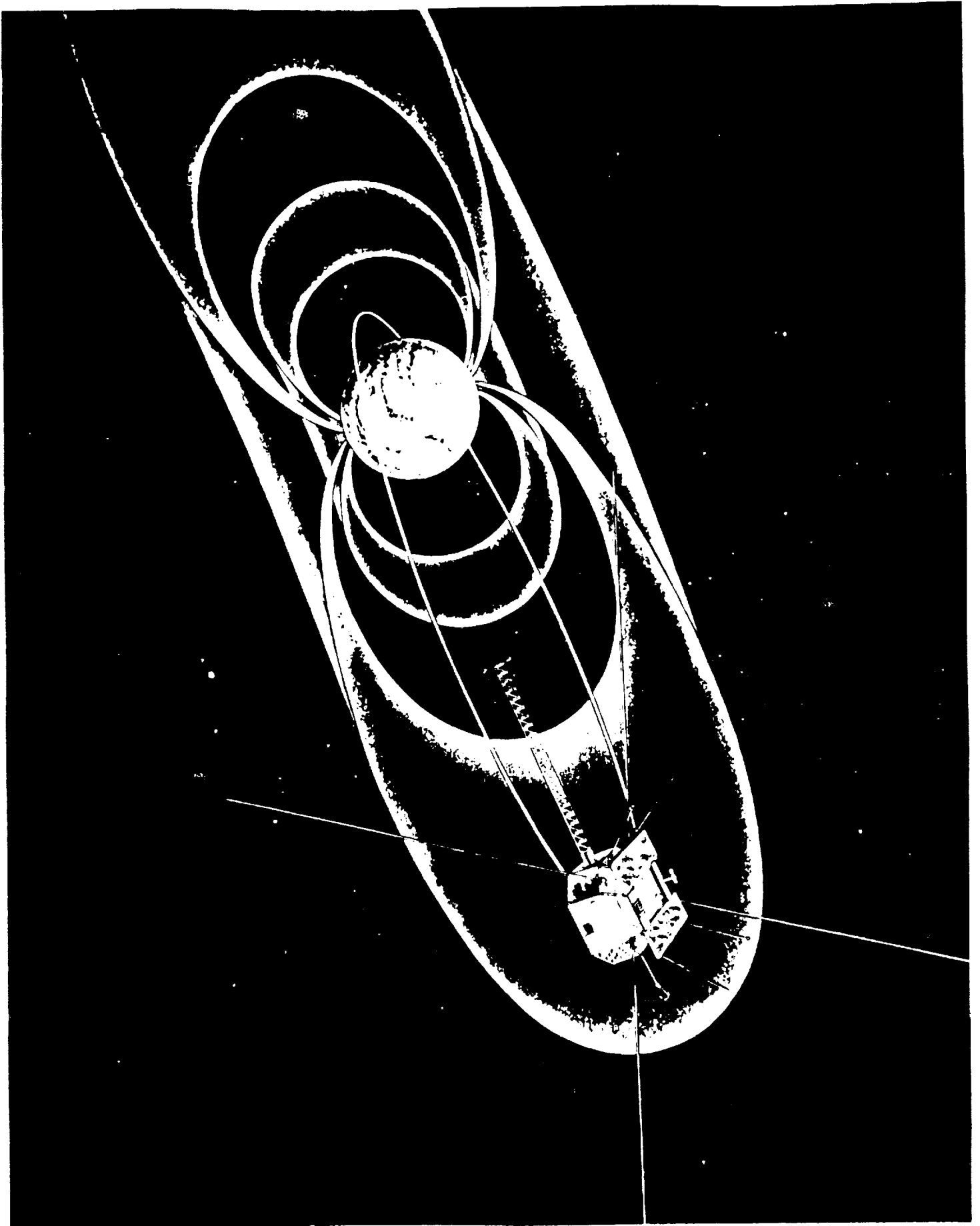
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**FINAL DRAFT**

**The  
Combined Release  
And  
Radiation Effects  
Satellite Program**

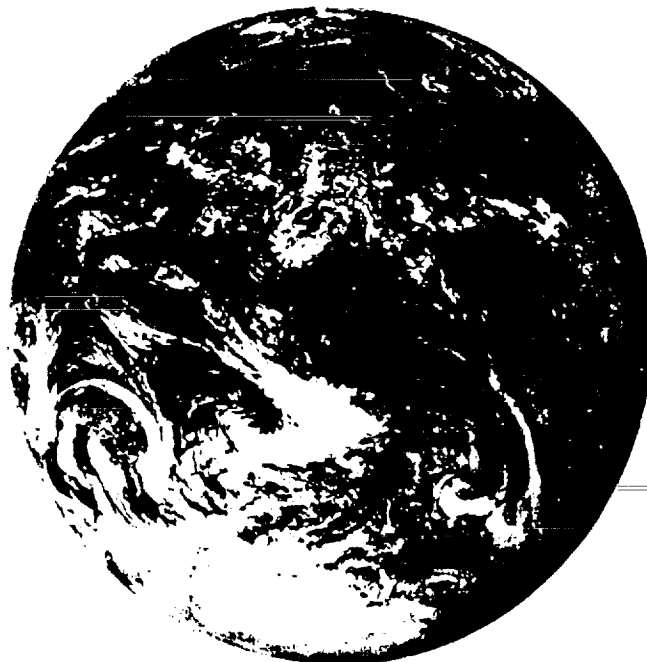
EARTHSPACE . . . . .	1
HOW EARTHSPACE AFFECTS US . . . . .	3
NEED FOR ACTIVE EXPERIMENTS . . . . .	5
TYPES OF CHEMICAL RELEASES . . . . .	6
CRRES PROGRAM SCHEDULE . . . . .	12
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PHOTOGRAPHING CHEMICAL RELEASES . . . . .	16



## EARTHSPACE

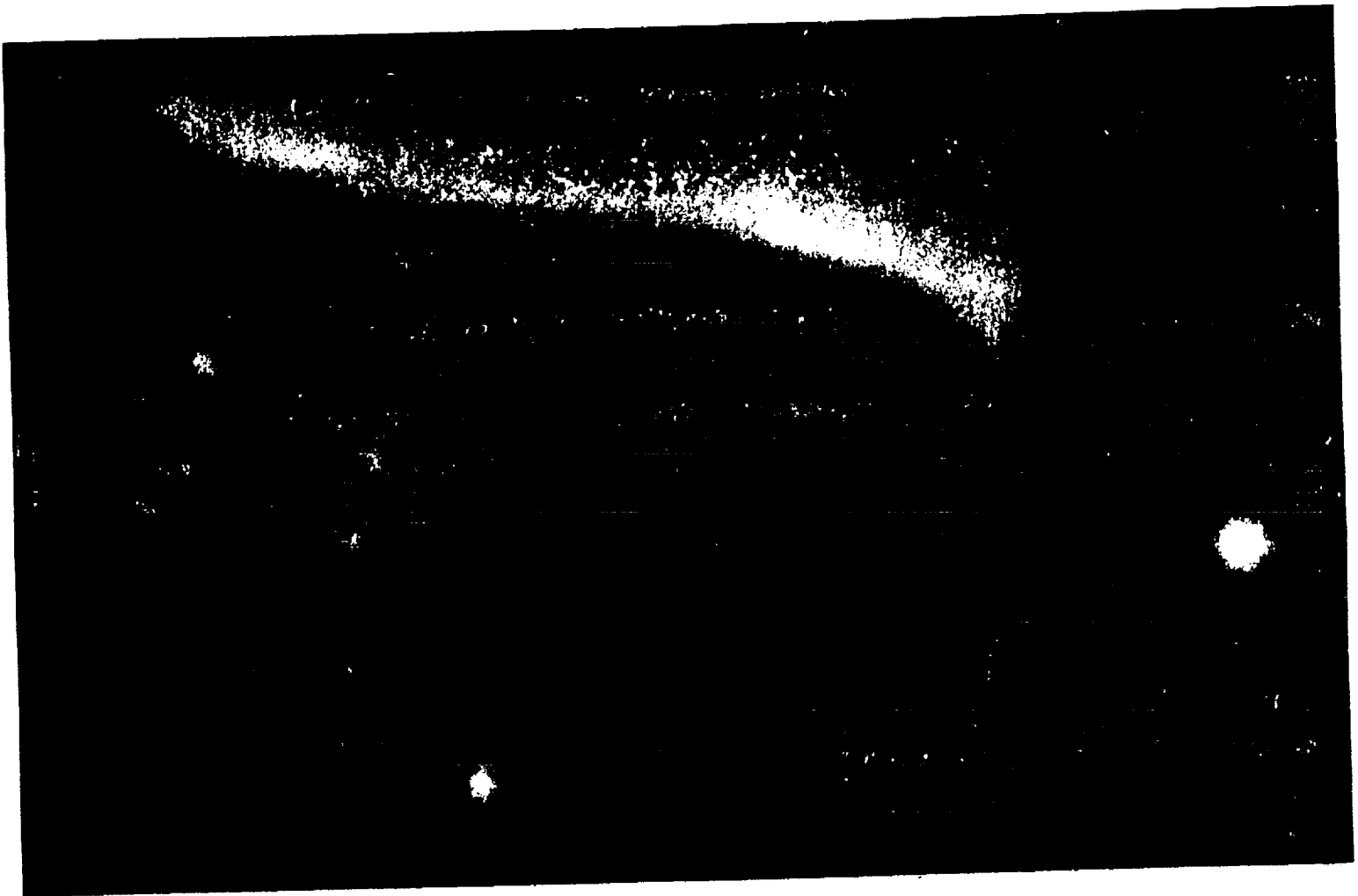
The National Aeronautics and Space Administration, and the Department of Defense, have joined in a program to study the space environment which surrounds Earth and the effects of space radiation on modern satellite electronic systems. The COMBINED RELEASE AND RADIATION EFFECTS SATELLITE (CRRES) will carry an array of active experiments with chemical releases, and a complement of sophisticated scientific instruments which will accomplish these objectives. Other chemical release active experiments will be performed with sub-orbital rocket probes. Effects on the space environment from the chemical releases will be studied, using an extensive network of ground-, aircraft-, and satellite-based diagnostic instruments.

We live in a thin shell of air on the surface of planet Earth. The sun provides energy in the form of light and heat, making life possible. Most of what we experience: wind, rain, heat, cold, and life itself, is made possible by the energy from the sun and the fortuitous place of Earth in the solar system. We are not too close, like Venus with its clouds of carbon dioxide and surface temperature of 700 degrees; nor are we too far or a bit too small, like Mars which lost its atmosphere millions of years ago. Above our atmosphere, above the air and clouds, not directly known to our senses; lies an exciting realm of magnetic fields, electric fields, radio waves, and atomic particles, that is as important as the air we breathe. This is EARTHSPACE, surrounding us with a protecting mantle of magnetic and electrical fields that collect and transmute energy from the sun.



The most obvious manifestation of Earthspace around us is the aurora, or the Northern and Southern Lights. Known to the ancients, these lights in the regions of the Boreal and Austral Poles were first interpreted as being supernatural in origin, and later attempts were made to ascribe scientific causes, such as sunlight reflecting from ice clouds high in the atmosphere. In the Middle Ages, the Italian scientist Galileo, while looking at the sun through a telescope for the first time, noticed dark

"spots" on the surface that were ever changing. As the sunspots were studied over the years, it was observed that the number of spots waxed and waned in an eleven-year cycle. Also noted, was that the chance of viewing the aurora, rose and fell with the number of sunspots. Thus began the realization that the sun "communicated" with the Earth in ways other than light and heat. This was the first real beginning of modern space physics.



## HOW EARTHSPACE AFFECTS US

Even before the era of direct space exploration with satellites, scientists had begun to perceive that electrically charged atoms flowing outward from the sun collided with the magnetic field of the Earth and played a significant role in creating the Earth's environment. Reception of radio waves over long distances showed the presence of a layer of conducting gas above the atmosphere. At the time, explorations were limited to ground-based instruments, and much of the important data necessary to build even a rudimentary understanding were not available.

The launch of the United States scientific satellite Explorer I came during the International Geophysical Year 1958. This was a time of increased awareness of the importance of magnetism, electric currents, and charged particles surrounding the Earth. The premier scientific discovery of Explorer I was the Van Allen Radiation Belt. This discovery showed that charged atomic particles, electrons and ions, were trapped within the Earth's magnetic field above the atmosphere and immediately began the scientific quest to understand where these particles came from and how they obtained high energies.

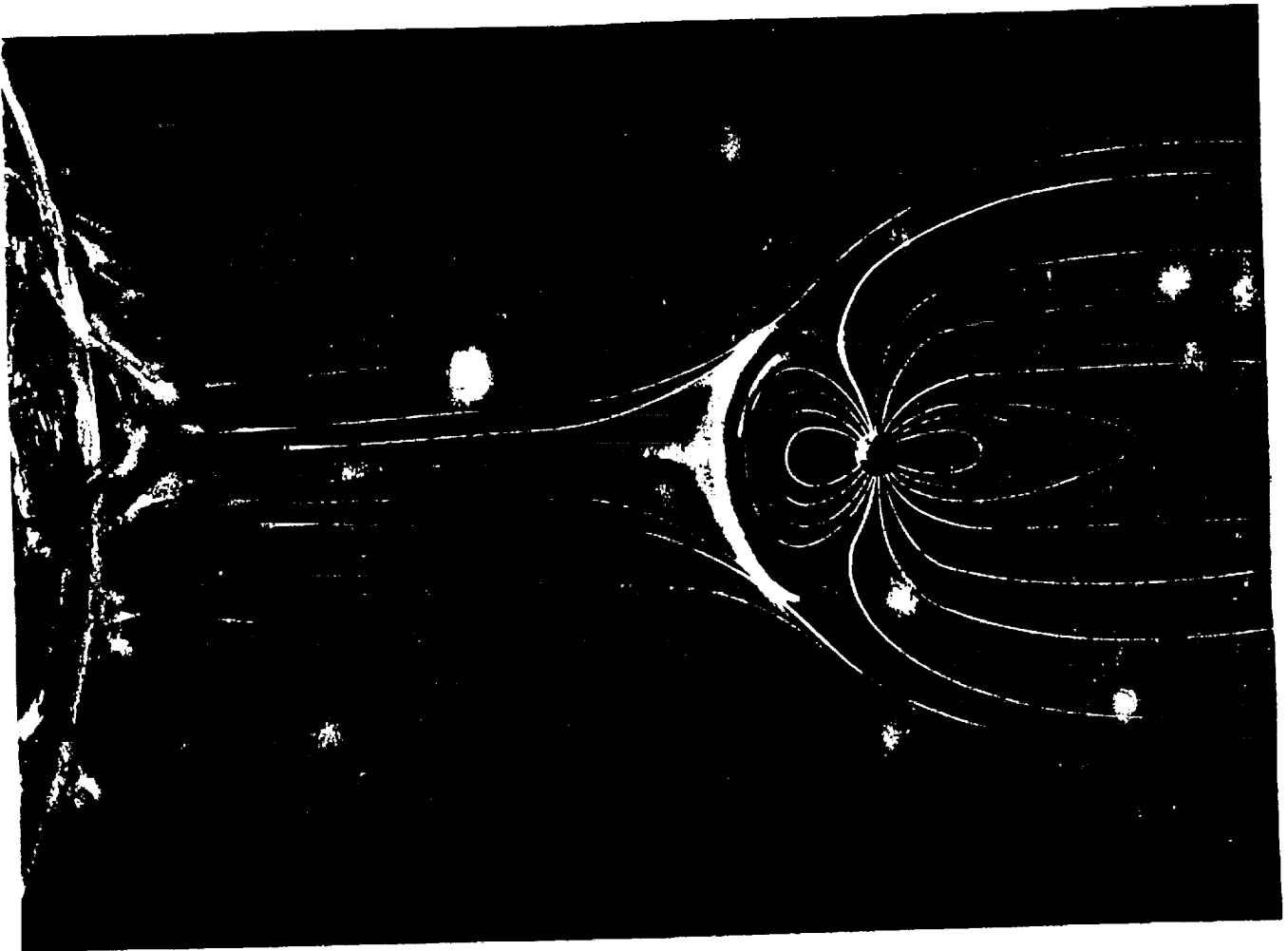
We are familiar with three states of matter; solid, liquid, and gas. Ice, liquid water, and steam, are three forms of a substance known to us all. A fourth state of matter exists in space, a state where the atoms are positively charged and share space with free electrons. This state of matter can conduct electricity, and interacts strongly with electric and magnetic fields. We call this state of matter a PLASMA.

Three decades of probing Earthspace with a wide variety of instruments have led to a fairly complete model of the essential features of the Earth's magnetic field and plasma environment. This region is known as the magnetosphere. The Earth and its atmosphere seem insignificant on this distance scale, but the Earth holds the dynamo which generates the magnetic field, and the atmosphere, which is a source of matter to the magnetosphere. Close to the Earth, the magnetic field looks like the familiar field of a pattern of iron filings around a bar magnet. This is called the dipole field, and on the surface of the Earth, it can be used for navigation with a compass.



Far from the Earth, as the magnetic field weakens, the hot plasma blowing from the sun, the solar wind, pushes against the magnetic field. The magnetic field is compressed on the side toward the sun and stretched out downwind to form a long tail. Even though the magnetic field is weak, it is still capable of holding within it masses of plasma with high energies.

Energetic charged particles constantly race along magnetic field lines and smash into the upper atmosphere in the polar regions, causing the beautiful aurora. The magnetosphere does not rest in one place. It is constantly storing energy and releasing it in sudden surges. These impulsive releases of energy and the changes in the magnetosphere



This static picture can only hint at the ever-changing nature of this system. The ultra-violet rays from the sun ionize the upper atmosphere, creating the electrically-conducting ionosphere and a source of plasma for the magnetosphere. The energy from the solar wind enters the magnetosphere and ultimately creates high-energy charged particles and large-scale current systems.

and ionosphere are very important to us, for they directly affect activities on Earth. Large currents generated in the magnetosphere and ionosphere influence terrestrial power systems and cause disturbances - even blackouts. During periods of geomagnetic storms, the ionosphere is "torn apart" into irregular structures, disrupting long-distance radio communication.

## NEED FOR ACTIVE EXPERIMENTS

We are using space more and more for activities which are now viewed as routine. Communications satellites, weather satellites, and navigation satellites, are all part of a global network, and we see their influence each time we turn on our television sets. These marvelous machines must operate in the environment of space; an environment often made hostile by high energy charged particles from the sun and the magnetosphere.

Satellite systems are becoming more sophisticated as a result of advances in microelectronics (more can be accomplished with the same power and weight), but the electronics are also more susceptible to radiation damage. The primary DOD mission on CRRES is to measure the present state of the Earth's space radiation environment, to increase the accuracy of the models of the environment, and to measure the effects of that environment on state-of-the-art microelectronic devices and solar cells.

The majority of space science investigations have been by measuring, either remotely or by instruments placed into space, coupled with applying the equations of chemistry and physics. Unlike a situation in a laboratory, it is not possible to bend the space environment to our will and perform a repeated measurement. The environment constantly changes, and our sensors are rapidly moving on space platforms. Imagine if we could perform a controlled experiment where we actually produced a perturbation in space and measured the effects. That would be an experiment in the true sense of the word!

The technique of active experiments has been used for many years in space science exploration. Injections of matter, electromagnetic waves, and charged-particle beams have been used with great success to probe our Earthspace. CRRES is studying Earthspace with the technique of chemical releases. This is the injection of specific substances into space environment for the purpose of a tracing, modification experiment, or simulation.

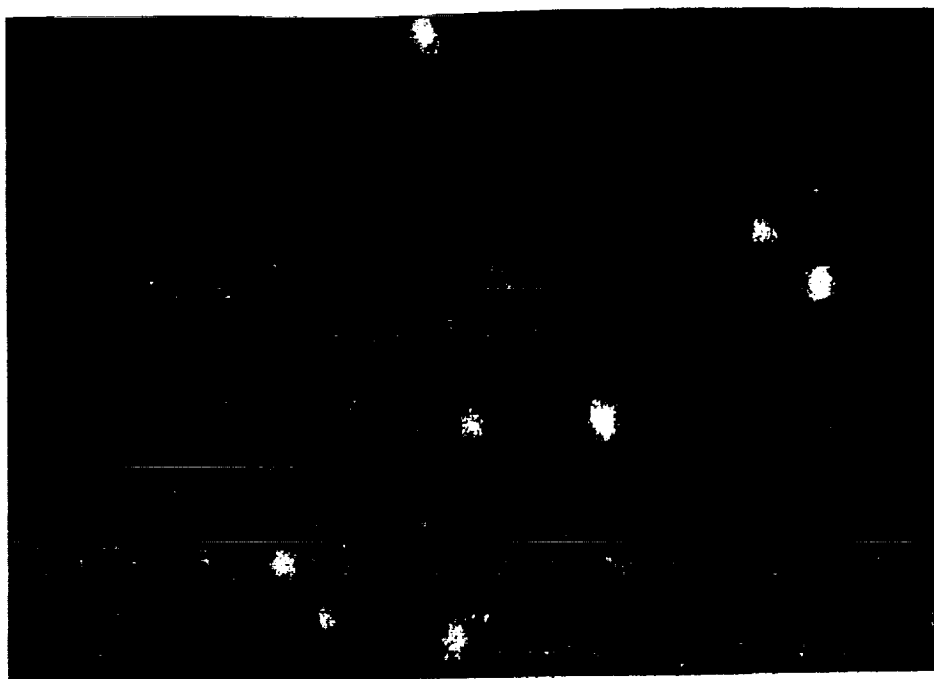
## TYPES OF CHEMICAL RELEASES

One of the most common experiments uses a release of one of a group of elements known as alkaline Earth metals (familiar elements such as sodium, barium, calcium, and lithium). These elements possess two very useful properties: The first is that in the presence of sunlight, electrons are stripped away and atoms become positively charged ions. Second, is that most of these elements glow with unique colors when lit up by sunlight, and are visible. In small amounts, these types of chemicals can be used as tracers - painting the magnetic and electric fields with glowing ions. This is the same idea as when smoke is injected into wind tunnels to see the air-flow pattern over airplanes; or injecting of radiopaque dyes into the body, so that certain structures will be visible on X-rays. Using larger releases, we can modify the environment with artificial plasmas, and the response of the system to this perturbation can be studied.

Another class of materials acts to decrease the charged particle density by chemical reactions. Common chemicals such as water vapor, hydrogen, and carbon dioxide all act to convert positively-charged particles to neutral atoms. A "hole" can be made in the space plasma, which can be a significant perturbation, leading to simulations of natural processes, or can modify the ionosphere to accomplish a certain objective.

The released chemical must be in vapor form for the effects to occur. Metallic materials are heated to high temperatures, thousands of degrees, in a canister packed with thermite. This thermite burns, and the excess heat energy vaporizes the material and ejects it from the canister into a cloud. In the case of liquids and gases, again it is necessary that the material be ejected in vapor form. External or internal heaters are used to heat the material before release.

The release of substances into the environment naturally raises concerns. Some of the materials such as sodium, barium, and lithium, are toxic or dangerous when in contact with humans. Others are harmless, (substances such as water vapor, carbon dioxide, and hydrogen). But the chemicals are released in space, rather than in the biosphere, and the amounts released are a few kilograms. Any chemicals that settled into the biosphere would be dispersed over an area hundreds of miles in size. Calculations show that the potential concentrations in the biosphere are much less than concentrations of the same substances resulting from human activities. (One of the by-products of burning coal is the release of barium which occurs in trace amounts in the coal. The total amount of barium released as a result of burning coal is estimated to be 10,000 tons per year.)

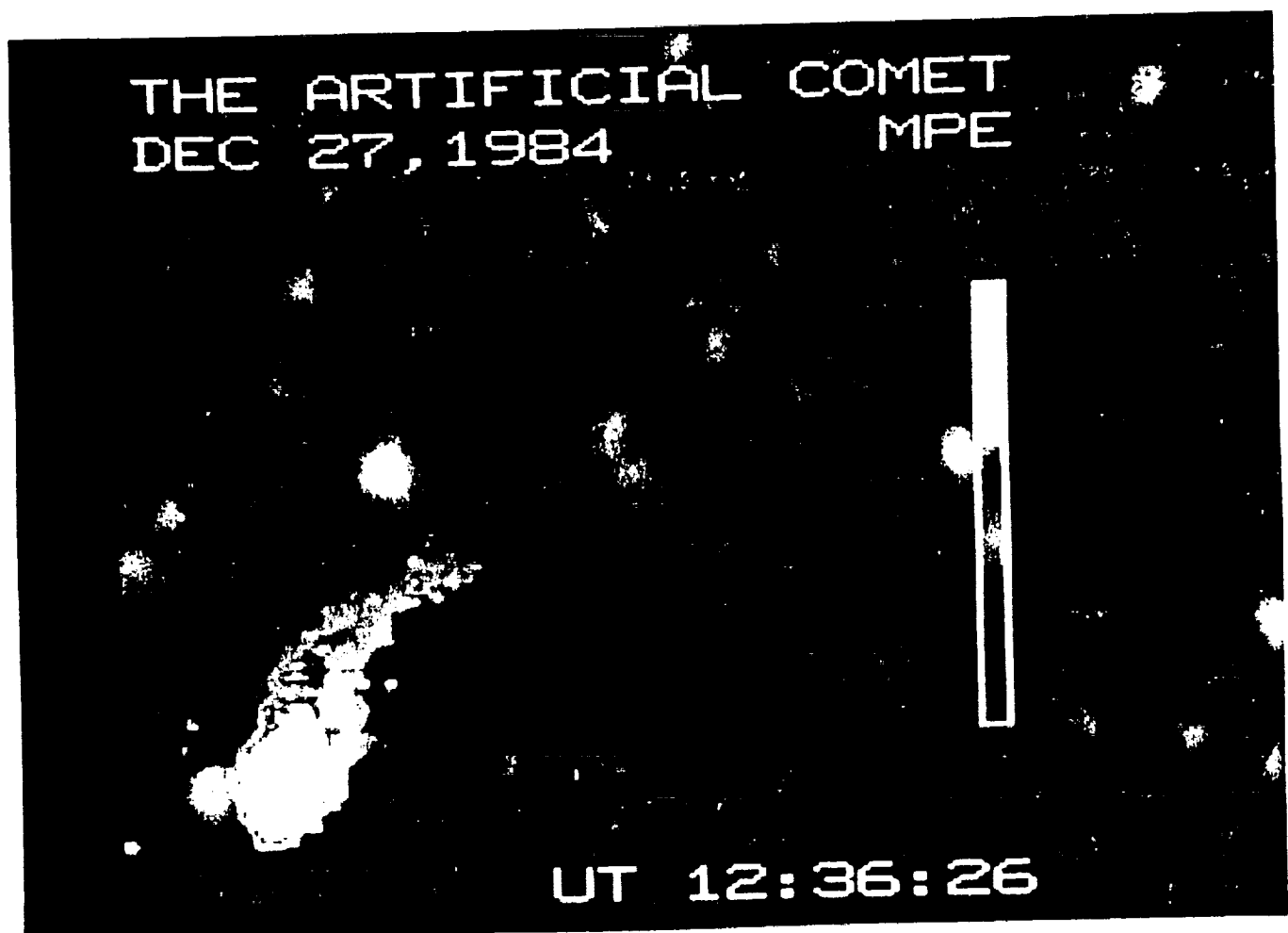


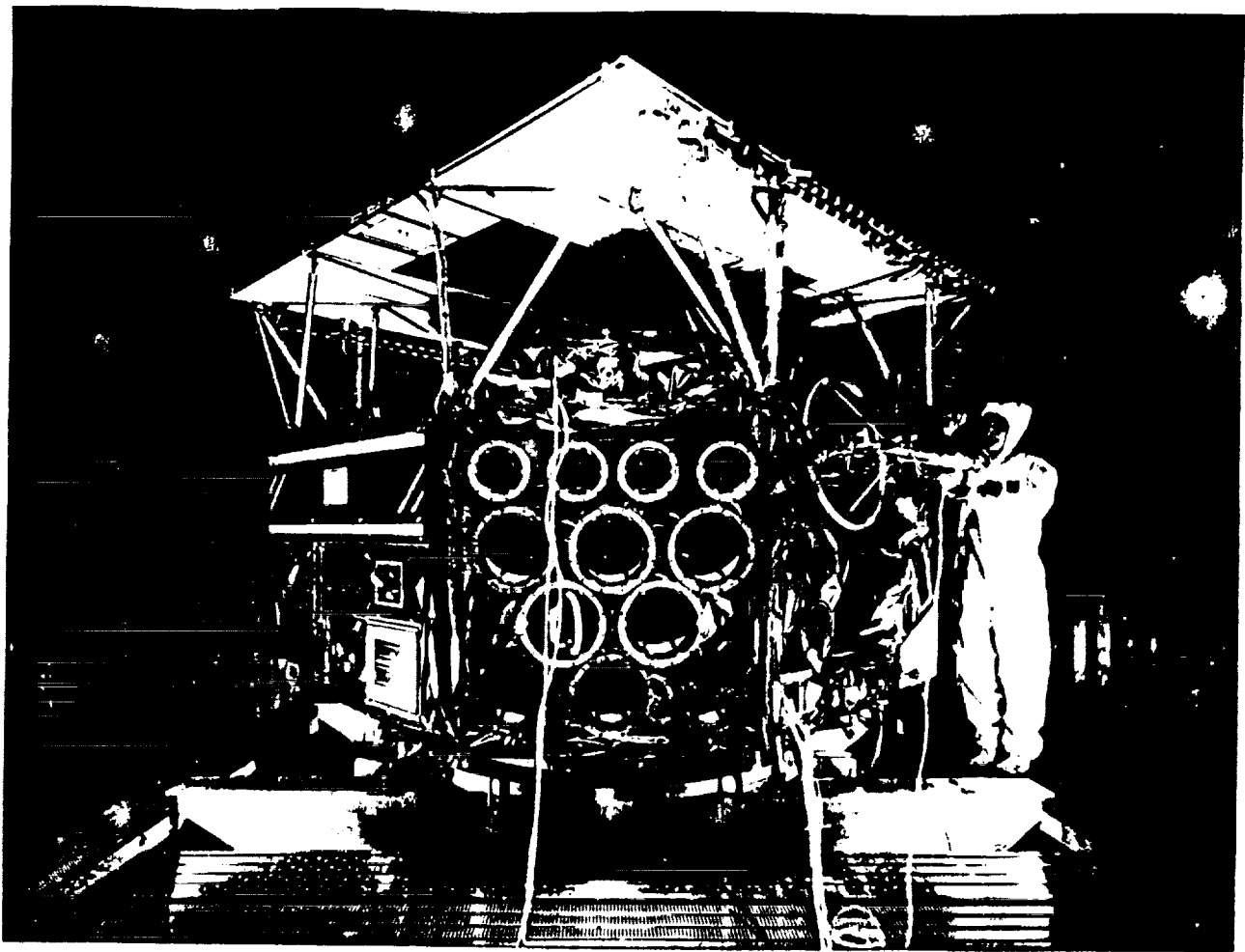
A photograph of barium and lithium release clouds shows the unique properties of these materials. Here the bright red is the emission from a cloud of neutral lithium atoms. Since the atoms are neutral, they are not affected by the electric and magnetic fields and they expand into a sphere.

The purple-colored cloud is from barium ions. Barium neutrals become ionized by sunlight in about twenty seconds. A definite streak has formed, and the barium ions are lined up along the magnetic field. The barium has been used as a tracer to "paint a picture" of the magnetic field, which otherwise we could not see.

CRRES is not the first mission to conduct chemical releases from a satellite. Earlier missions such as Chemically Active Material Ejected in Orbit (CAMEO) and Active Magnetospheric Particle Tracer Experiment (AMPTE), conducted releases of barium and lithium in the magnetosphere and in the solar wind. AMPTE was a joint program of the United States, The Federal Republic of Germany, Great Britain, and Argentina. It was designed to trace particle motion over large distances of Earthspace,

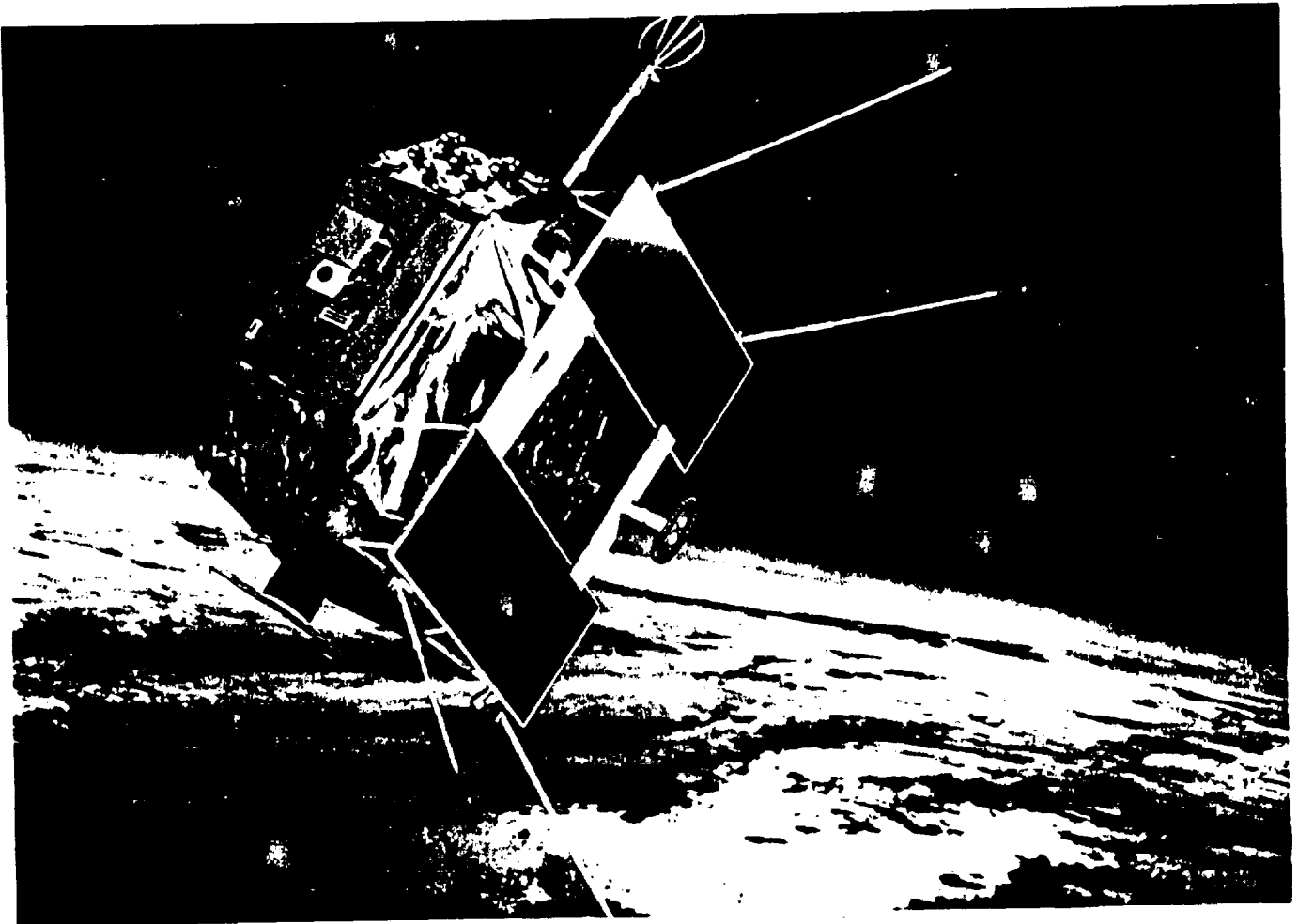
and to simulate natural phenomena. The photograph of a comet is really an artificial comet created by a release of barium in the solar wind. This is a "false color" rendering, with the intensity of the measured light represented by the color. Blue represents the weakest light, and white the brightest. The resemblance to an actual comet with a coma, and the curved tail of ions, is remarkable. It illustrates the power of the chemical release technique used to study our solar system.



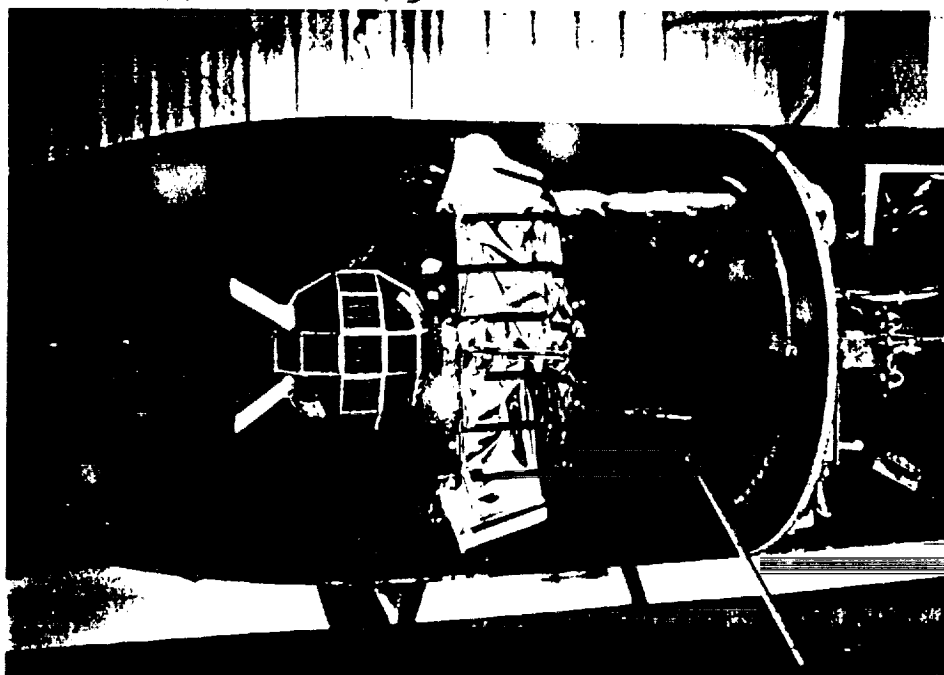
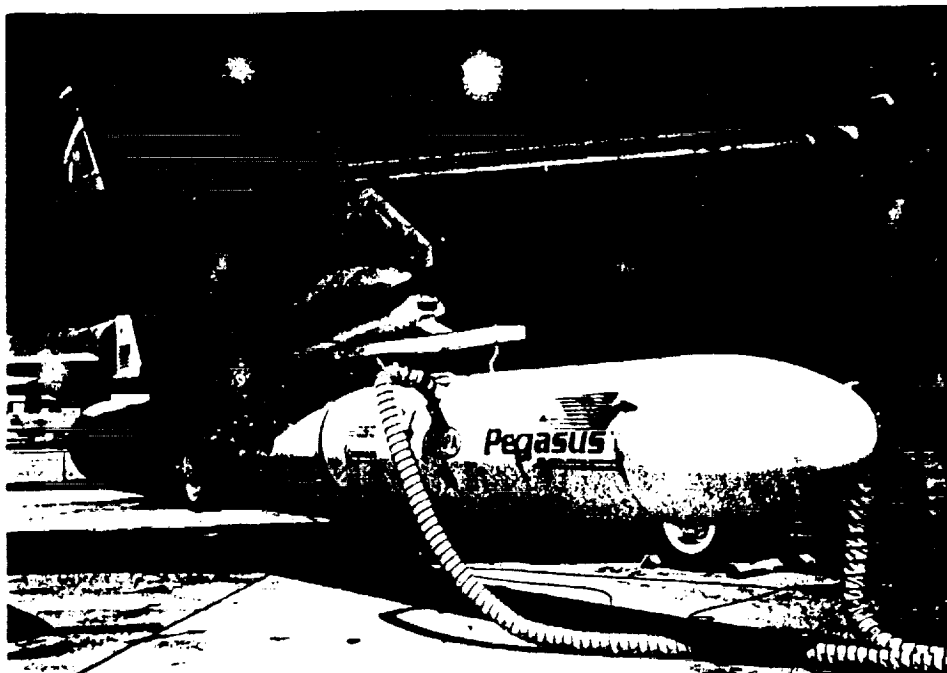


A satellite carrier of chemical releases starts the chemical cloud at its orbital velocity. At first, the released cloud is moving at the same speed as the satellite through space, and the atoms and ions of the release have a large amount of kinetic energy (or energy of motion). The CRRES Program will make good use of this in conducting a series of unique experiments in the ionosphere. Other experiments will take advantage of the highly elliptical orbit of CRRES, with altitude varying between 350 and 36,000 kilometers, to reach to the outer regions of the magnetosphere for experiments studying high-energy radiation.

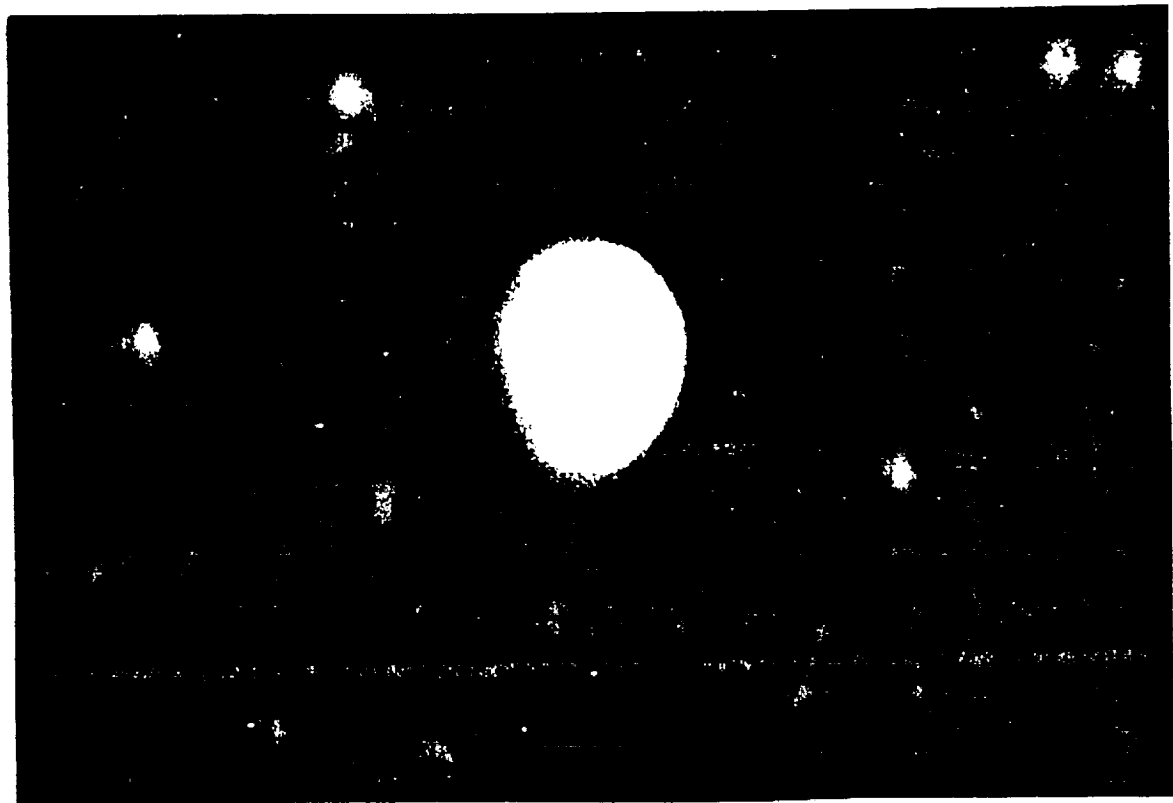
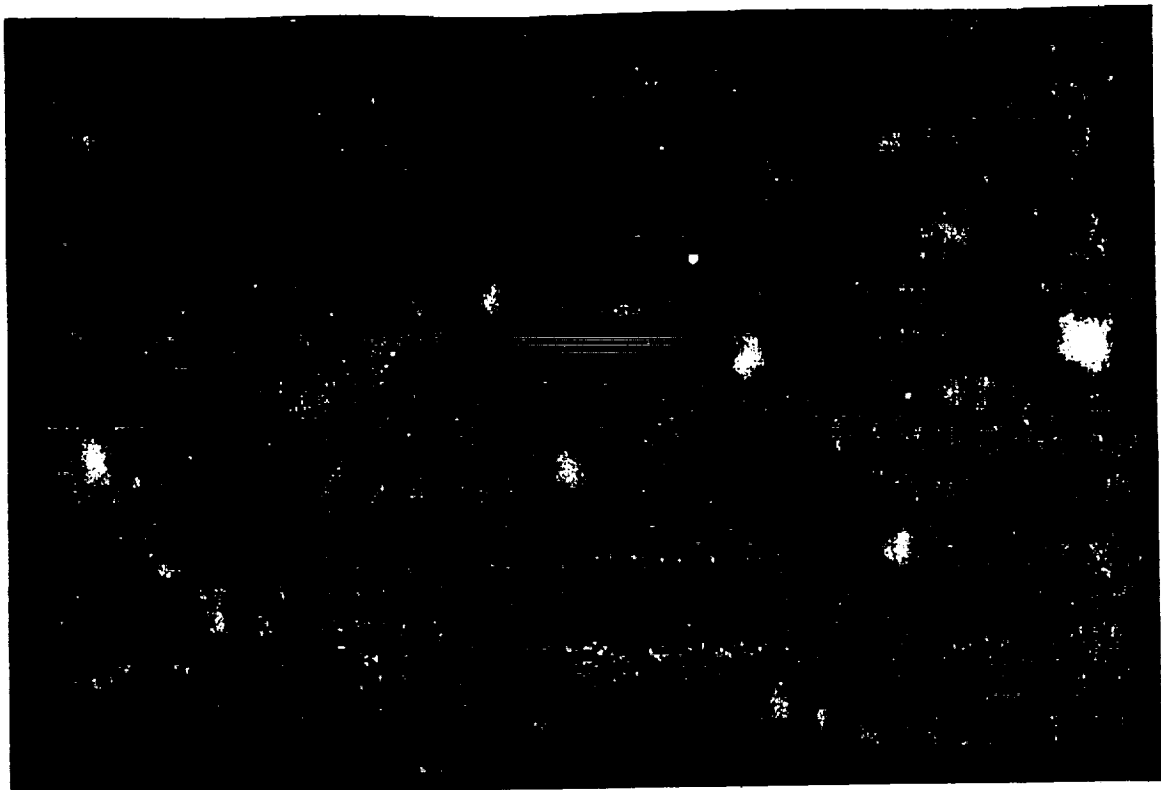
The artist's conception of CRRES in orbit, shows the bays holding the chemical canisters, the solar panels for electric power, and the long booms and antennas which are a part of the scientific sensor package. The orbit of the satellite will be known to a high degree of accuracy, and the scientific investigator will determine the exact point for a chemical release experiment to occur. Twenty-five minutes prior to the actual release, the canisters are ejected from the spacecraft by springs, and at the instant of ignition, the canisters are 3 kilometers or more away from the spacecraft. Releasing at a distance protects the delicate spacecraft surfaces and instruments.



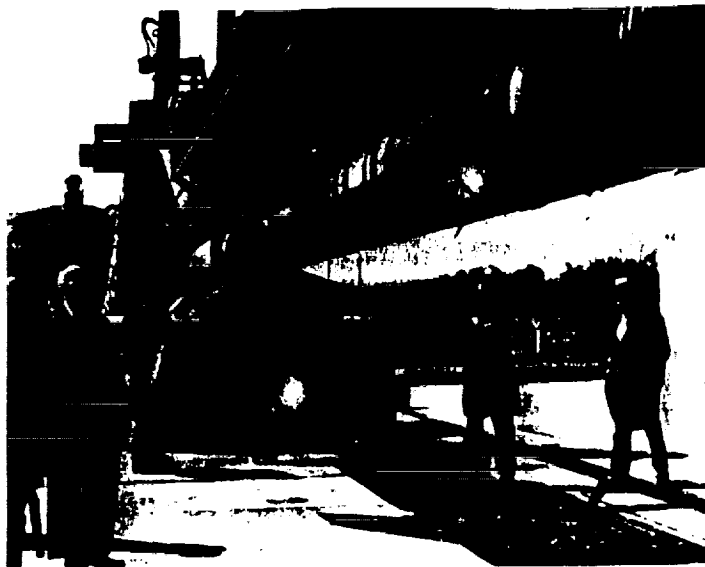
The CRRES Program has taken a "hitchhiker" ride on the first launch of the PEGASUS rocket, to make two barium releases over Canada. The PEGASUS is a private launch vehicle development. On its first flight, PEGASUS carried an experimental DOD satellite and NASA chemical canisters. The releases, in April, 1990; were used to study the electric structure of the space regions in the aurora.



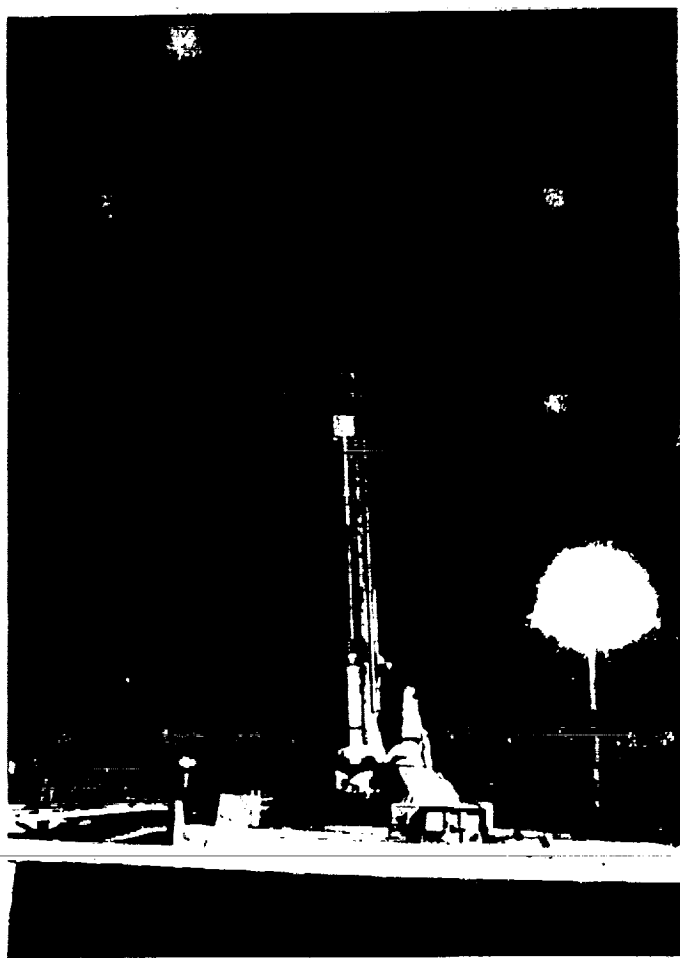
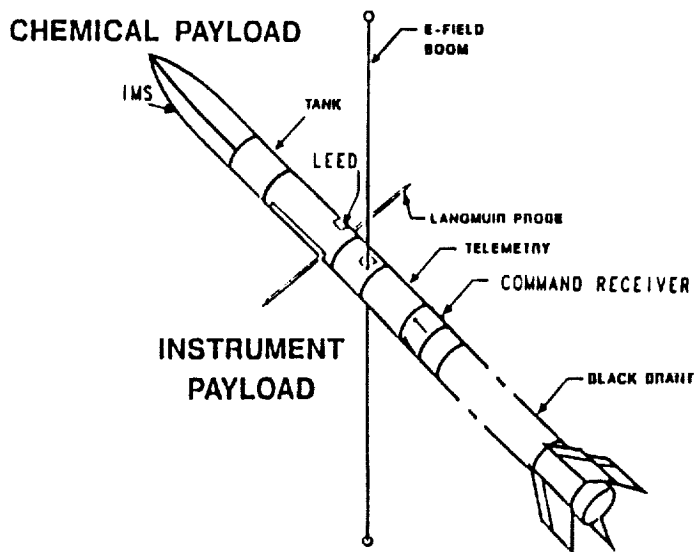




A sounding rocket is a versatile chemical release carrier if orbital velocity is not required.



This Terrier-Black Brant was used to conduct a program of two vapor releases to create ionospheric density depletions, or "holes." A sounding rocket can carry large amounts of a chemical to create a large-scale perturbation, and in general can be more precisely targeted in space and time. For example, some of the CRRES Program experiments require targeting a release to within a circle 40 kilometers in diameter at an altitude of 250 kilometers within a time period of 10 minutes. Such accuracy is routine with a sounding rocket, but is impossible with a non-maneuverable satellite.



## CRRES PROGRAM SCHEDULE

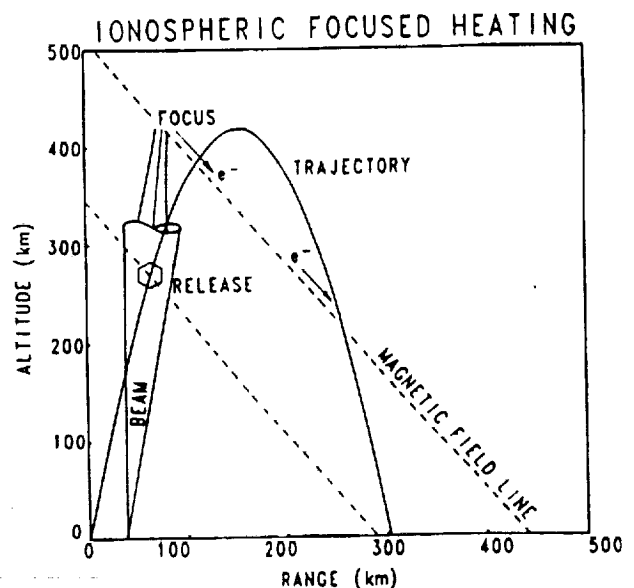
The CRRES Program will span a period of more than one year. The PEGASUS releases occurred during April, 1990. The CRRES Spacecraft will be launched in June, 1990. The first releases from the CRRES Spacecraft will occur in August, 1990, with a pair of releases in the vicinity of American Samoa in the South Pacific. These releases will test a theory of Critical Velocity Ionization, a process leading to an anomalously large amount of ionization as a gas moves at high speed through the ionosphere.

As the apogee (high point) of the CRRES orbit moves into the midnight region of the Earth's magnetosphere, artificial plasmas (ion clouds), will be injected to learn how the resident particle populations react to this intrusion. "Dumping" of trapped particles is expected to occur. The particles are perturbed out of their stable trajectories in the magnetic field, and rush along the magnetic field to collide with the upper atmosphere, creating an artificial aurora.

July and August, 1990, will begin a series of sounding rocket releases of an ionospheric depletion vapor from Kwajalein Atoll, Marshall Islands. These releases are to study the formation of irregularities in the ionosphere—a phenomenon known as Spread-F.

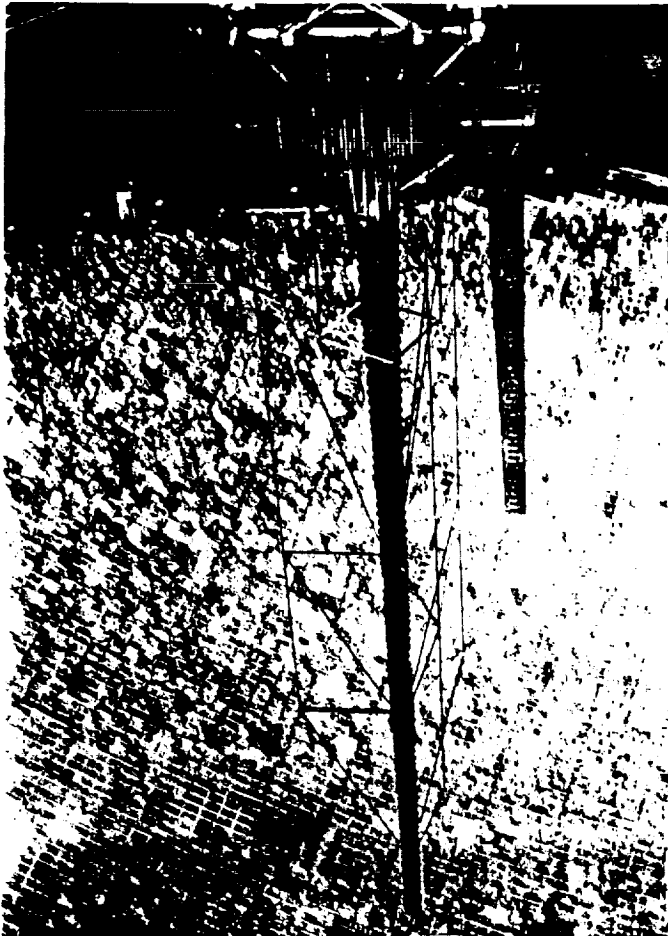
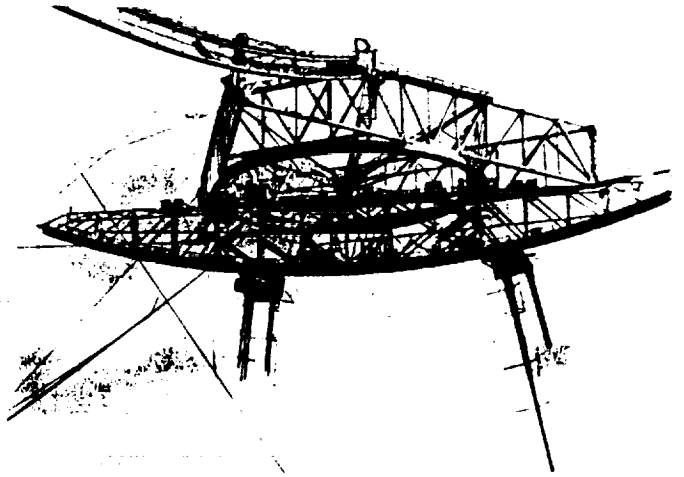
The CRRES Program will conclude with an ambitious campaign of satellite and sounding rocket releases in the area of the Caribbean in June and July, 1991.

This campaign will feature releases easily visible from the Southeastern United States in the pre-dawn hours. The objectives include studying the motions of ions for long distances along the line of force of the magnetic field, and studying the response of the ionosphere to specific, controlled perturbations. "Arches of glowing ions" along the magnetic field will be made with an injection at high velocity from the CRRES Satellite, and, as the sketch illustrates, will be visible to high-sensitivity cameras over a very large area of the northern and southern hemispheres. In a perturbation experiment, the release of a depletion vapor will create a "hole." This will focus from the beam of a high-powered radio transmitter. Scientists will be able to study how the ionosphere reacts to high levels of input energy, which happens during a major solar flare.

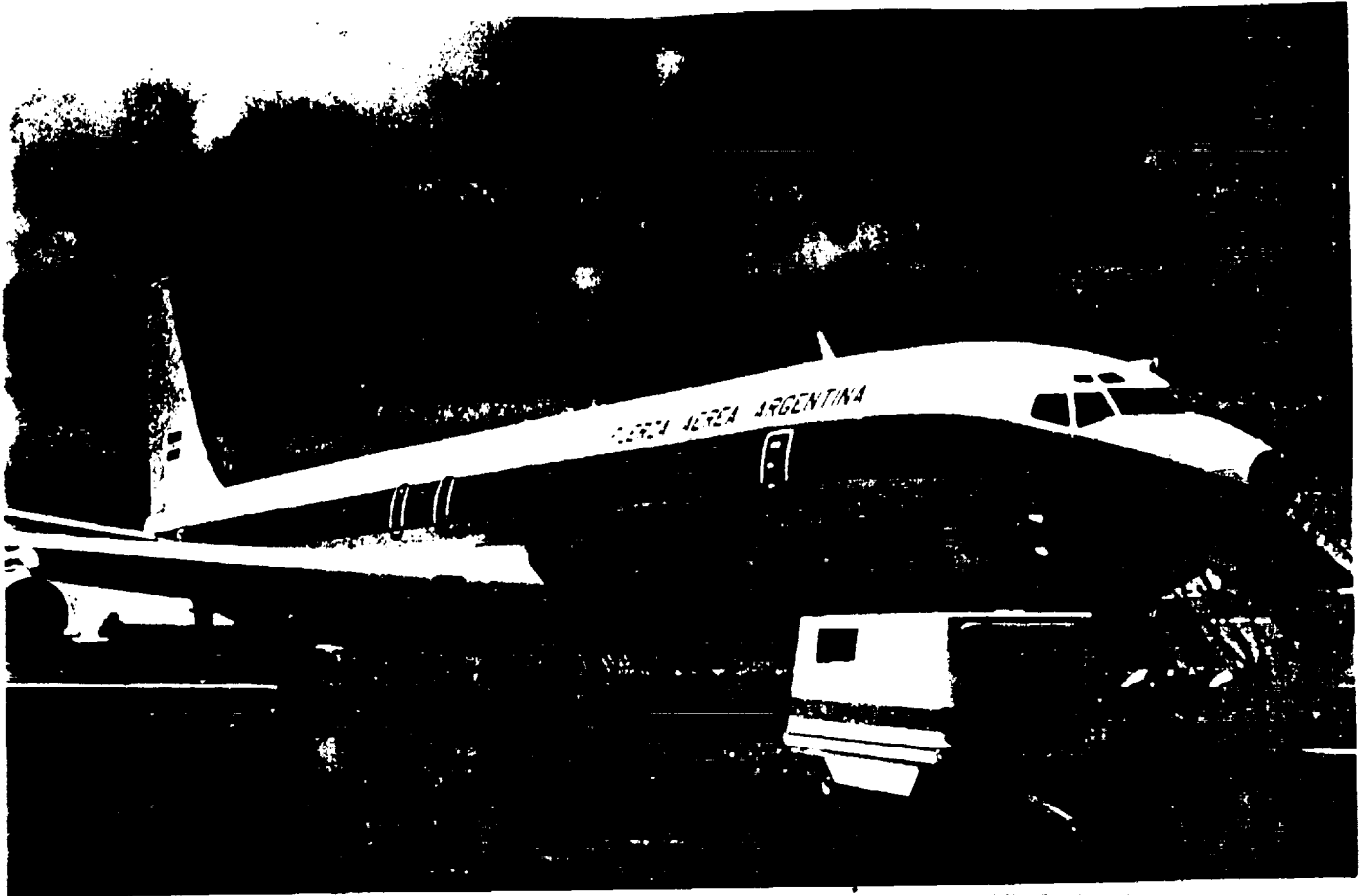


## INTERNATIONAL SUPPORT

The CRRES Program is international in scope, with participation by scientists from the United States, Puerto Rico, Canada, Germany, Argentina and the Soviet Union. Optical and radio observatories will be located on the Marshall Islands, on Fiji and American Samoa in the South Pacific, in Canada, on Martinique, Anguilla, Aruba, Dominica, and Guadeloupe in the Caribbean, and in Argentina, Chile and Ecuador.



The special radar facilities at Arecibo, Puerto Rico; Kwajalein, Marshall Islands; and Millstone Hill, Massachusetts; will be used as primary diagnostic tools. These radars transmit powerful pulses of radio energy into the ionosphere and analyze the weak returns from the electrically-charged particles there. The amount and speeds of the ionospheric particles and how they are changed by a chemical release perturbation can be measured with high precision using these radars.



Cameras carried aloft in aircraft will be operated to guard against loss of data from locally bad weather. One such aircraft, a Boeing 707 operated by the Argentine National Commission for Space Research, will provide all-important optical data from the southern end of the ion jets moving along the magnetic field lines. This and other special research aircraft from NASA and the United States Air Force will contain cameras, gyroscope platforms to stabilize the images, precise navigation systems, and sophisticated computer-controlled pointing systems to aim the cameras at the right point in the sky.

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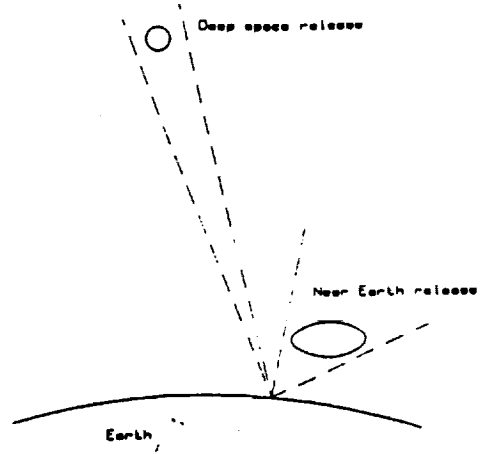
## PHOTOGRAPHING CHEMICAL RELEASES

The chemical releases of the CRRES Program, particularly those using barium and lithium, will be visible to the human eye, and can be photographed with photographic equipment already owned by the serious amateur. The high-altitude releases in January-February, 1991, will be visible over the entire Western Hemisphere, and the Caribbean releases in June-July, 1991, will be visible from the entire Caribbean, northern South America, and a significant portion of the southeastern United States. This encompasses two broad categories of chemical releases; those near Earth at less than 1500 kilometers altitude (the Caribbean releases), and those in deep space, greater than 1500 kilometers altitude. The types of equipment required to photograph these two types of releases are quite different.

Near Earth chemical release photography is considerably easier and requires minimal photographic equipment. All that is needed is a camera with a fast lens and an adjustable shutter with a "T" or "B" setting for taking time exposures. Fast film, a tripod, and a cable release, complete the ensemble.

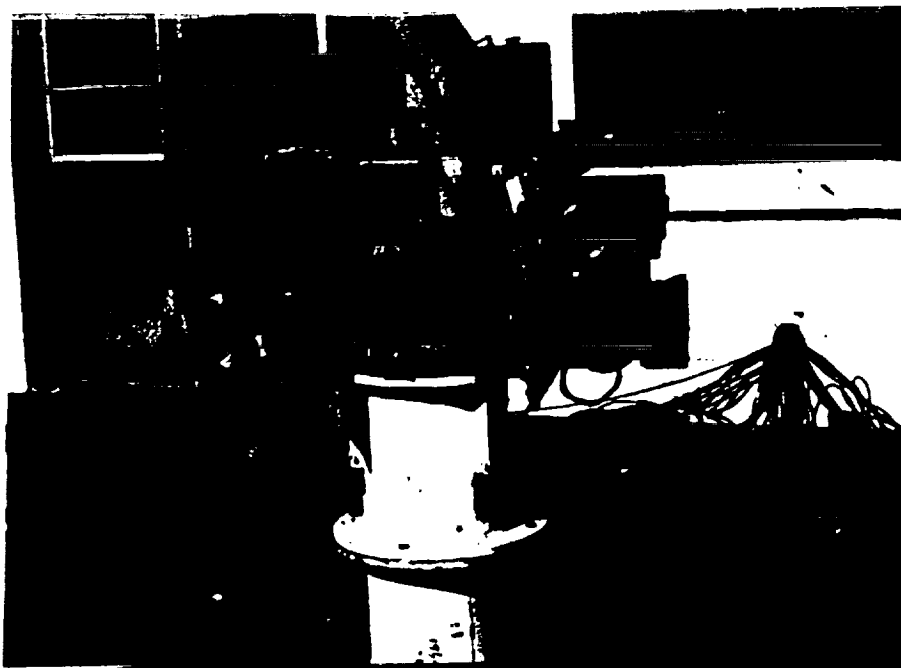
To obtain good photographs of deep space releases, fast long focal length systems are required, and clock drives to compensate for the Earth's rotation are desirable. The optical systems can be either fast telephoto lenses (very expensive), or astronomical telescopes (less expensive).

In either type of instrument the speed of the system is very important and should not be slower than F 4.0. The field of view for deep space releases should ideally be in the range 4-8 degrees, and long focal length lenses are not needed or desirable.



A rough approximation of the brightest parts of a chemical release cloud are contained within a cloud 100 kilometers in diameter. At 500 kilometers distance, typical of a near-Earth release, this cloud subtends 6 degrees of arc. For a 35 MM camera, a lens in the range 50-70 MM is a good match. Deep space releases will subtend angles down to perhaps 0.5 degrees, but pointing uncertainties and lens speed dictate a FOV of 4-8 degrees as mentioned above.

When compared to daytime photographic subjects, chemical releases are faint, diffuse objects. Photography of chemical releases is similar to photography of the aurora borealis. Fast lenses and



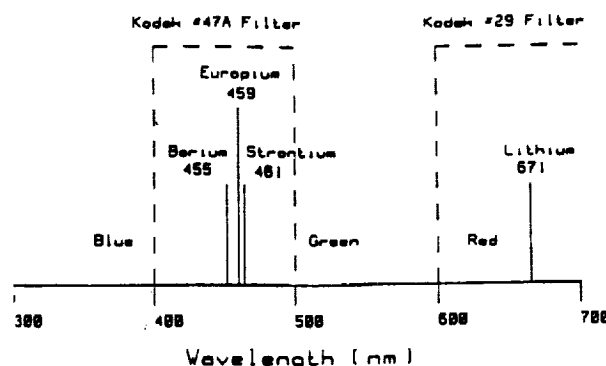
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fast films are the primary requirement, but the techniques are by no means difficult. The photograph of the red lithium cloud and the purple barium cloud shown earlier, was taken with a 35 MM camera, 50 MM lens, at a slant range of 600 kilometers.

Many fast films are available for low-light level photography. For color photographs, transparency film is desirable for many reasons. Many of the fastest films are available in transparency film only. High resolution is not needed for chemical release photography, and hence small format film pushed one or two stops is more than adequate.

Scientists studying chemical releases use a large variety of instruments, including optical instruments. As a result, most releases will be accomplished under conditions of darkest skies, no moon and solar depression angles greater than at least 12, and preferably 18 degrees. For the best results, a dark sky site far from artificial lights is very desirable, but becoming increasingly hard to find. If light pollution is a problem, filters may be used to isolate the color of the chemical release being photographed, and thus improve the signal-to-noise ratio. The accompanying figure shows the positions of the resonance lines of common chemical release substances and the filters required.



The value of a chemical release photograph to a scientific study is significantly enhanced with a few simple measurements. Obviously the time of the photograph is crucial, and either a receiver capable of tuning standard time signals such as WWV, WWVH, or CHU; or a good watch recently set to a time standard is essential. Of course, the operator must remember to log the time of each frame, or post-release times with a stopwatch. The latitude and longitude of the observing location is important, and this can be determined to sufficient accuracy with USC & GS topographic maps or sectional aeronautical charts. Approximate values of the elevation and azimuth (be sure to state whether relative to true, or magnetic north) are useful, but the exact pointing information comes from the star field in the photograph.



HOW WILL THE AMATEUR OBSERVER  
KNOW WHERE TO LOOK ?

NASA will make available the time and coordinates (latitude, longitude, altitude) of a release through public media such as astronomy magazines and bulletin transmissions. There are a number of software packages that allow the observer to calculate look angles in azimuth, and elevation or right ascension and declination.

Chemical releases are also interesting to radio amateurs and professionals studying HF and VHF propagation and scatter. A chemical release acts like a meteor trail of enhanced ion density, but with much longer duration. In another sense, the effects are like a small-scale Sporadic-E region. The chemical release scientist will be studying some of the release effects with HF bi-static paths, VHF coherent scatter radars operating near 50 and 137 mhz, and with satellite signals passing through the ion clouds to Earth-based receivers.



PHOTOGRAPHS NASA except:

Aurora Pg. 2	Gary Emerson, Emerson Enterprises
Barium/Lithium Release Pg. 7	John Kierein, Ball Space Systems Division
AMPTE Pg. 8	Dr. Arnoldo Valenzuela, Max-Planck Institute
CRRES Pg. 9 & Pg. 10	Ball Space Systems Division
PEGASUS Pg. 11	Jerry Stiles, Franklin Research Institute
Sounding Rocket Pg. 12	Melanie A. Alzmann, University of Alabama
Arecibo Radar Pg. 14	Morgan W. McCook, University of Alabama
Lithium Release (Upper) Pg. 18	Gary Emerson, Emerson Enterprises
Barium Release (Lower) Pg. 18	John Kierein, Ball Space Systems Division
Atlas-Centaur (Above)	General Dynamics Corporation

## CRRES AS A PROGRAM

CRRES is a joint program of the National Aeronautics and Space Administration, and the United States Air Force Space Test Program. The Space Physics Division of the Office of Space Science and Applications, NASA Headquarters, Washington, D.C. 20546 is responsible for the chemical release Program. The CRRES Satellite and scientific campaign is managed by the CRRES Project Office, FA21, NASA Marshall Space Flight Center, Huntsville, Alabama, 35812. CRRES sounding rockets are under the management and technical direction of Wallops Flight Facility/NASA Goddard Space Flight Center. The prime contractor for the CRRES Spacecraft is Ball Space Systems Division of Boulder, Colorado, and the chemical canisters are the responsibility of the Franklin Research Institute and General Sciences Corporation of Philadelphia, Pennsylvania. The launch vehicle for CRRES is the Atlas-Centaur, developed by General Dynamics Corporation. Coordination and documentation of the Investigators Working Group, is the responsibility of the University of Alabama Research Institute.

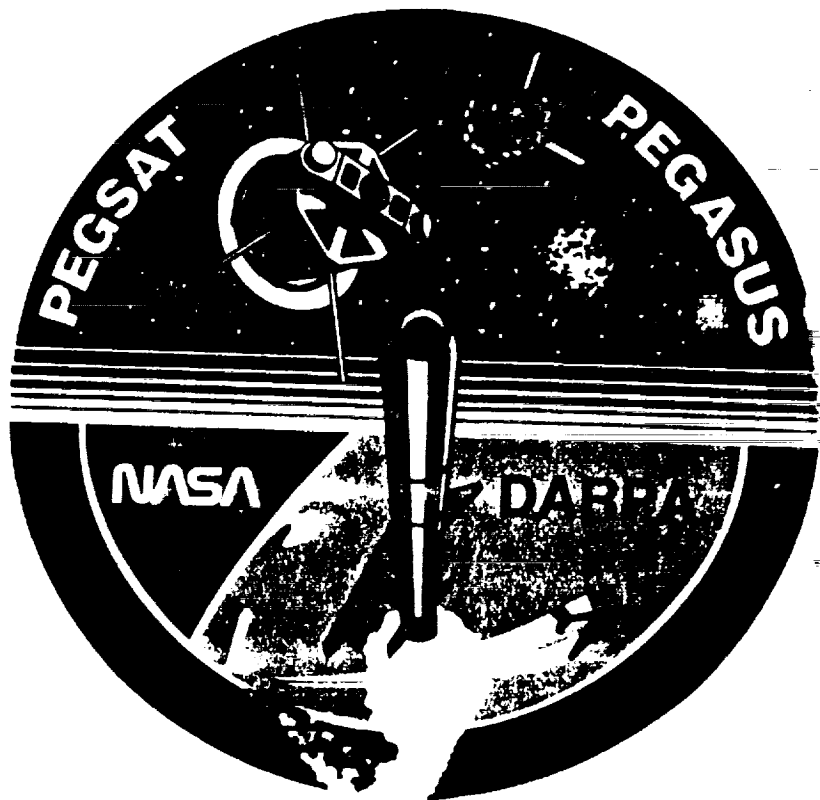
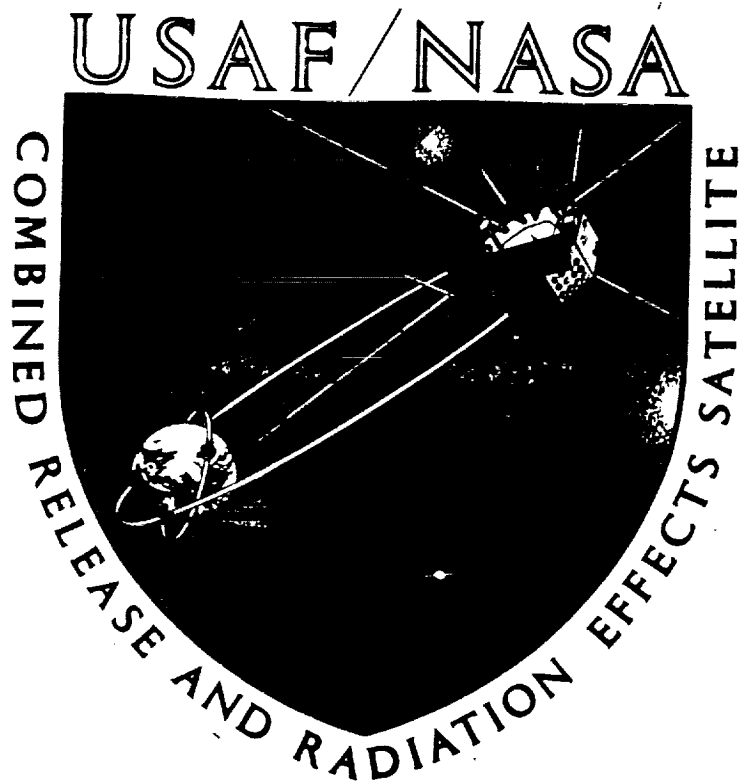
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